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Research Article

ICU staffing and patient outcomes in English hospital Trusts: A longitudinal observational study examining ICU length of stay, re-admission and infection rates

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ABSTRACT

Aims: This study examines the association between registered nurse (RN) staffing configurations and potentially nurse-sensitive patient outcomes in English Intensive Care Units (ICU) and to assess changes as the COVID-19 pandemic unfolded.
Methods: This was a longitudinal retrospective study analysing routinely collected patient and electronic roster data from 12 ICUs in NHS hospital trusts (January 2019–December 2022). The variables of interest were RN staffing levels and staff mix factors. The outcomes considered were unit-acquired infections, length of stay and readmissions. The relationships were analysed using covariate-adjusted generalised linear mixed models over the entire period and separately for pre-pandemic, pandemic and post-pandemic periods.
Results: Data from 12 ICUs included 52,267 admissions, with RN staffing levels (mean) peaking during the later pandemic period (34.2 h per patient day [HPPD], Standard Deviation (SD) = 12.1) compared to pre-pandemic levels (27.0 HPPD, SD = 8.5). Higher RN HPPD were associated with reduced readmission risk overall, with the strongest protective effect during early pandemic periods. No statistically significant association was found between RN staffing and length of stay overall, though a 5 % reduction occurred during the late pandemic period ($p = 0.035$). The presence of low levels of nurse managers (band 7 +) was associated with significantly reduced readmission risk (1.3 %-point decrease, $p = 0.011$), which arose from an association during the pandemic, but increased length of stay across all periods.
Conclusions: Higher RN staffing levels were consistently associated with reduced ICU readmissions, demonstrating the protective effect of adequate nursing resources. However, the impact of senior nursing staff on other patient outcomes was complex and context-dependent, varying across pandemic periods.
Implications for Clinical Practice: The findings emphasise the importance of evidence-based staffing policies that optimise skill mix and leadership deployment to improve ICU patient outcomes.

Introduction

Intensive care units (ICUs) are high-stakes environments where patient outcomes are heavily influenced by the quality and quantity of nursing care [1]. The increased risk of mortality has been widely studied in terms of relationships with RN staffing [1], but other important outcomes, including length of stay (LoS), unit-acquired infections, and readmissions much less so. The risk of poor patient outcomes, including

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unit-acquired infections in ICUs, is high, with prevalence rates reaching up to 20 % in some hospitals [2]. Also, patient readmissions to the ICU are another important outcome, with rates as high as 25 % in some hospitals [3,4]. The importance of nurses being involved in management has been shown indirectly through studies of Magnet hospital accreditation [5].

A recent systematic review of longitudinal studies including ICU settings reported mixed findings on the association between RN staffing levels and LoS, infections and readmissions. The reviewed studies have a serious risk of bias due to inadequate risk-adjustment. This means that any detected association between staffing levels and patient outcomes might be at least partly explained by high patient acuity and existing co-morbidities [6,7]. In addition, the COVID-19 pandemic introduced unprecedented challenges, including surges in patient acuity, resource constraints, and rapid changes in care protocols, which may have altered these relationships beyond the pandemic period [8,9]. Although prior research has examined RN-to-patient ratios, limited evidence exists regarding how RN team composition (e.g. RN skill-mix and presence of nurse managers) influences ICU outcomes such as the development of unit-acquired infections, increased LoS and readmissions to the ICU.

Therefore, this study aims to fill these gaps by exploring longitudinal associations between RN staffing, skill mix, and patient outcomes in English ICUs over almost four years, encompassing the pre-pandemic, pandemic, and post-pandemic periods. By providing insights into the impact of staffing on ICU outcomes prior to, during and after the pandemic, this study offers valuable evidence for optimising ICU staffing strategies in both crisis and non-crisis settings.

Methods

This was a longitudinal retrospective study using routine patient data from 12 ICUs from 11 hospitals in six acute National Health Service hospital Trusts in England. The RECORD guideline [10] was followed in reporting this study. Patient data were provided by the Intensive Care National Audit and Research Centre (ICNARC) Case Mix Programme (CMP), the national data registry for ICUs in England, Wales, NI and Ireland. We extracted data from March 2019 to December 2022. We extracted daily staffing data from electronic roster systems and linked this to patient data to explore how variation in staffing was associated with the following indicators of patient safety and care quality: duration of stay, risk of any readmissions and risk of unit-acquired infections after ICU admission.

Data and variables

We included adult patients (medical, elective surgical and emergency surgical cases) with at least one overnight stay in ICU. The outcomes were the length of stay (defined as total days of ICU hospitalisation per patient from admission to discharge), unit-acquired infections (i.e. infections from C. difficile, MRSA, VRE detected, or antimicrobial treatment that occur 48 h or more after admission), and readmissions (defined as returns to the same ICU within 30 days of discharge, with outcome ascertainment available until 30 days after the last patient admission). The patient records included case mix (acuity) adjustment based on the latest (2023) ICNARC risk model (revised to consider COVID-19 related risks), which scores mortality risk (between 1–100). The calculation is based on age, dependency before admission, system (the primary reason for admission), physiological parameters and past medical history and shows better discrimination ($C > 0.84$) than the APACHE II score [11,12].

The staffing data included worked shifts of nurses in the ICU, which we converted into worked hours per day shift interval (7 am to 6.59 pm) and night shift interval (7 pm to 6.59 am) to align approximately with typical nurse shifts. We used the pay band (grade) from the national grading system and job post to identify and classify RN staff: junior RN staff nurses (band 5), experienced staff nurses (band 6), nurse managers (band 7 and above). These categories reflect skill, competence and seniority [13,14]. Junior RN staff nurses are responsible for assessment, planning, delivery and evaluation of patient care. Experienced staff nurses have experience working in intensive care and often have an ICU qualification. In addition to the responsibilities of junior nurses, they also often provide managerial oversight on a unit, delegating responsibility amongst the team. Nurse managers do not routinely deliver care on the unit, instead they oversee a larger team of nurses and are responsible for coordinating care, providing advanced clinical assessments, developing policies, leading quality improvement initiatives, etc.

The patient records and the worked shifts were linked to calculate the RN hours per patient day(s) (HPPD): the number of staff hours divided by patient days. This accounts for changes in ward staffing. The available data was from 2019 to 2022. We subdivided into 4 periods before, during and after the COVID pandemic: *pre-pandemic* (03/19–02/20), *early pandemic* (03/20–02/21), *later pandemic* (03/21–02/22), and *post-pandemic* (03/22–12/22).

The main indicator for staffing was RN HPPD, the absolute HPPD for band 5 and 6 registered nurses, because they provided hands-on (direct) patient care. We also calculated the proportion of care hours worked by band 6 (i.e. band 6 RN HPPD divided by RN HPPD) for each shift.

These variables were averaged across the patients' stay (mean). As an alternative to absolute HPPD, we created a variable of low staffing calculated as any case when the mean HPPD was less than 24 RN HPPD. This threshold for understaffing was based on UK standards for RN staffing in the ICU with a 1:1 RN-to-patient ratio for patients requiring ventilation and support for multi-organ systems (level 3 care) [15,16]. We calculated absolute HPPD worked by band 7 + RNs (averaged over the stay (mean)) and classified these hours as categories of none (0), low (0.1–1.9), medium (2–3.9) and high (>=4). This decision was taken because the distribution was bimodal, indicating mixed patterns of deployment (see Table 1). Band 7 and above staff are likely to take supervisory roles (not delivering 'hands-on' care) and may also be deployed in purely managerial/educational roles, which were not clearly recorded. Thus, as a group, they have a limited and uncertain contribution to direct patient care.

Data management

Data preparation and analyses were carried out using R version 4.3.1 (R Project for Statistical Computing) with RStudio (Posit) [17]. For data wrangling and summary statistics, we used *tidyverse 2.0.0* [18] and GTsummary 1.7.2 [19] packages respectively. The numerous job titles identifying the nursing staff in the roster dataset were categorised into major staff groups (mentioned above) with the open-source *OpenRefine* software (version 3.7.7). Missing data in the patient-level data set was resolved using multiple imputations by predictive mean matching using the MICE R package. RN HPPD values were trimmed to the range between 10–65 based on the upper quartile Q3 + (1.5 x interquartile range). This reflects most staff shifts and admissions. The decision was informed by clinical experience and knowledge of ICU staffing guidelines [13,15] which would indicate that any staffing outside these ranges was either data errors or substantially atypical. For analysis of the linked dataset, we used the linear mixed effect modelling (*lme4)* package 1.1–34 [20]. The significance level for statistical inference was set at $P < 0.05$.

Statistical analysis

We used the generalised linear mixed models (GLMM) framework to model the gamma distribution of the length of stay (linear regression) [21,22], and the binary outcomes of unit-acquired infections and readmissions (logistic regression). Modelling was at the patient level, although ICUs were included as random effects in the models, ensuring that variations across the ICU units were accounted for. In our primary analysis, we considered absolute staffing (RN HPPD) on the unit over the

Table 1
Staffing levels and staff mix.

	ALL PERIODS				pre-pandemic				early pandemic				later pandemic				post-pandemic			
VARIABLE	Mean	(SD)	Median	(IQR)	Mean	(SD)	Median	(IQR)	Mean	(SD)	Median	(IQR)	Mean	(SD)	Median	(IQR)	Mean	(SD)	Median	(IQR)
RN staff nurse (band 5 & 6) hours per patient day (HPPD)	31.1	(11.2)	27.8	(16.5)	27.0	(8.5)	24.8	(11.9)	31.2	(11.2)	28.9	(14.4)	34.2	(12.1)	30.6	(20.4)	32.7	(11.8)	27.6	(20.5)
% of band 6 staff nurse HPPD (%)	25.3	(14.0)	19.6	(15.4)	24.7	(12.1)	20.8	(12.3)	25.7	(13.1)	20.9	(15.3)	26.1	(16.0)	19.2	(29.1)	24.7	(14.6)	17.9	(18.3)
RN band 7 + HPPD	2.0	(1.8)	1.7	(2.5)	1.6	(1.6)	1.4	(2.2)	2.3	(1.9)	2.1	(2.6)	2.1	(1.8)	1.7	(2.5)	2.0	(1.7)	1.6	(3.0)
Length of stay (days)	6.6	(10.9)	3.0	(5.0)	5.5	(8.7)	3.0	(5.0)	7.6	(11.4)	4.0	(6.0)	6.8	(11.9)	3.0	(5.0)	6.7	(11.7)	3.0	(5.0)
	n	(%)			n	(%)			n	(%)			n	(%)			n	(%)		
% unit acquired infections	6841	(13 %)			1700	(12 %)			1994	(15 %)			1761	(13 %)			1382	(12 %)		
% readmissions	4909	(9.4 %)			1147	(7.8 %)			1448	(11 %)			1303	(9.9 %)			1011	(9.1 %)		
%Day of low staffing (<24 HPPD)	16,672	(32 %)			6583	(45 %)			3628	(27 %)			3178	(24 %)			3283	(29 %)		
RN band 7 + HPPD categories																				
None (0)	11,529	(22 %)			3963	(27 %)			2267	(17 %)			2701	(20 %)			2598	(23 %)		
Low (0.1–1.9 HPPD)	17,977	(34 %)			5786	(40 %)			3791	(29 %)			4533	(34 %)			3867	(35 %)		
Medium (2–3.9 HPPD)	15,283	(29 %)			3317	(23 %)			4994	(38 %)			3873	(29 %)			3099	(28 %)		
High (4 + HPPD)	7478	(14 %)			1558	(11 %)			2236	(17 %)			2110	(16 %)			1574	(14 %)		
Total (N)	52,267	(100 %)			14,624	(100 %)			13,288	(100 %)			13,217	(100 %)			11,138	(100 %)		

patient's stay; we explored staff mix factors individually and in combination. The models were adjusted for patient case-mix using the 2023 ICNARC risk score. Other patient-level covariates included in the base model were sex, time of day of admission (day or night), and month of admission; similar to some of the risk factors adjusted for in previous studies [23–26]. The staffing variables (proportion of band 6 RNs) and nurse managers (band 7) were added separately. The combined multivariable model included all the staffing variables. For unit-acquired infections and readmissions, we estimated staffing effects using average marginal effects (AME) to represent expected absolute changes associated with a one-unit change with other variables at the mean, while effects for length of stay were estimated as a ratio, indicating the relative effect of a 1-unit change.

Relative model quality (fit) was evaluated using Akaike Information Criterion (AIC) with a preference for models with smaller values. Overall predictive performance was evaluated using the area under the curve (AUC) statistic (unit acquired infections and readmissions) and r^2 statistic (gamma-transformed LoS), with preference for models with higher values [22,27]. We carried out sensitivity analyses to check the sensitivity of our results to different ways of measuring staffing (e.g. low staffing), and different pandemic periods (i.e. before, during and after COVID-19).

Approvals

The ethics approval for this and the broader study (NIHR funder reference: 135168) was obtained from HRA (IRAS 316,667 and REC 23/SW/0028) and the University of Southampton Ethics Committee (ERGO reference: 80440). Data were requested from ICNARC via their Data Access Advisory Group. A waiver of informed consent was applicable because all the data supplied was anonymous [28].

Results

Across the 12 ICUs, we had data from 58,791 ICU stays. Nursing hours and skill mix were obtained from data describing 1,045,440 shifts worked by RNs, and we calculated staffing for 52,267 ICU admissions. The linked dataset comprised 52,267 records linking patient details to the mean of staffing experienced during all the days of the patient's stay from admission to discharge (Fig. 1). Overall, the mean RN HPPD was 31.1 (SD = 11.2), while that of band 7+ RNs was 2.0 (SD = 1.8). The mean proportion of band 6s (i.e. the proportion of band 6 RNs expressed as per cent) was 25.3 % (SD = 14.0) (Table 1).

Staff nurse hours per patient day (RN HPPD) peaked at a mean of 34.2 (SD = 12.1) during the later pandemic, from the lowest point during the pre-pandemic period (27.0 (SD = 8.5)) (Fig. 2a). Note that ICU staffing was prioritised during the pandemic, with staff deployed from other areas (where elective activity was cancelled and other admissions limited) to ensure adequate ICU capacity. On average, the proportion of band 6 senior nurses (SN) was highest during the late pandemic period (Fig. 2b). Absence of band 7 RN managers (i.e. 0 HPPD) was most frequent during the pre-pandemic phase and least frequent during the early pandemic phase (Table 1). Low RN staffing occurred more frequently during the pre-pandemic and least commonly during the late-pandemic period (Fig. 2c). The mean length of stay was highest during the early pandemic period (7.6 days (SD = 11.4) (Fig. 2d). The rates of ICU-acquired infections and readmissions also peaked during that period at 15 % and 11 %, respectively (Figs. 2e, 2f). For context, needs of patients changed over the course of the pandemic, with mean days of advanced respiratory support doubling from about 2.5 pre-pandemic to about 5 during the early pandemic, and reducing to about 3.5 post-pandemic (Supplementary Table 1).

The best model fit (based on AIC) was most frequently achieved when all staff mix factors were included, and so we focus on reporting these. Models with low staffing alone are reported in the Supplementary Table 2. In general, the estimated effects of low staffing were similar in these models.

Associations between RN staff nurse HPPD and outcomes

Overall, when patients were exposed to more RN HPPD, the risk of readmission was reduced with a 0.6 % reduction for each hour increase in the average staffing across the stay (Average Marginal Effect [AME] −0.006 (95 %CI −0.011- −0.001), p = 0.019) (Table 2). The direction of this association remained consistent across different COVID-19 periods, although the strength of association declined and became non-significant in later and post-pandemic periods. There was no, overall, statistically significant association with length of stay, but every additional RN HPPD was associated with a 5 % reduction in length of stay in the late pandemic period (exp beta [ratio] 0.95, 95 % CI 0.90–1.00). In contrast, during the pre-pandemic period, higher RN staffing was associated with increased length of stay (ratio 1.15, 95 % CI 1.10–1.20, $p < 0.001$; similarly, the point estimate in the post-pandemic period was also in the direction of increased length of stay. No significant associations were observed between RN staffing and unit-acquired infection in any period.

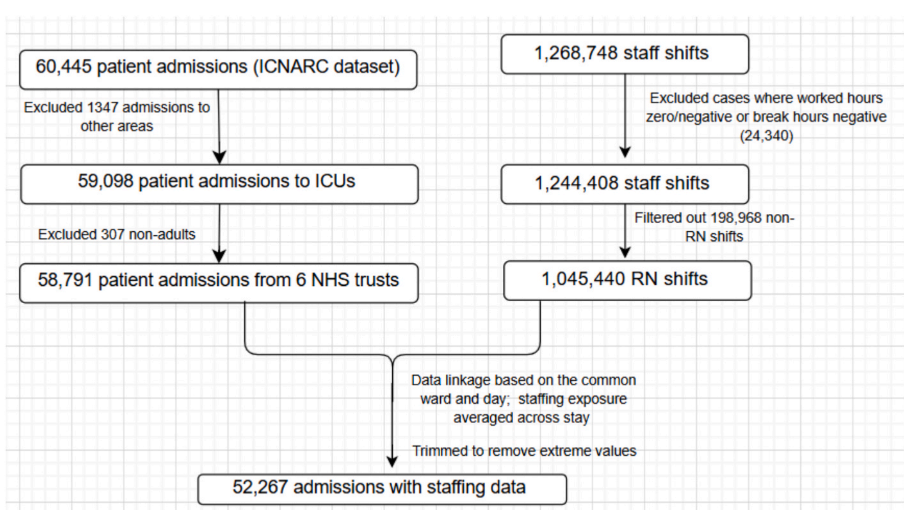

Fig. 1. Flow diagram describing how the final analysable dataset was derived from the raw data.

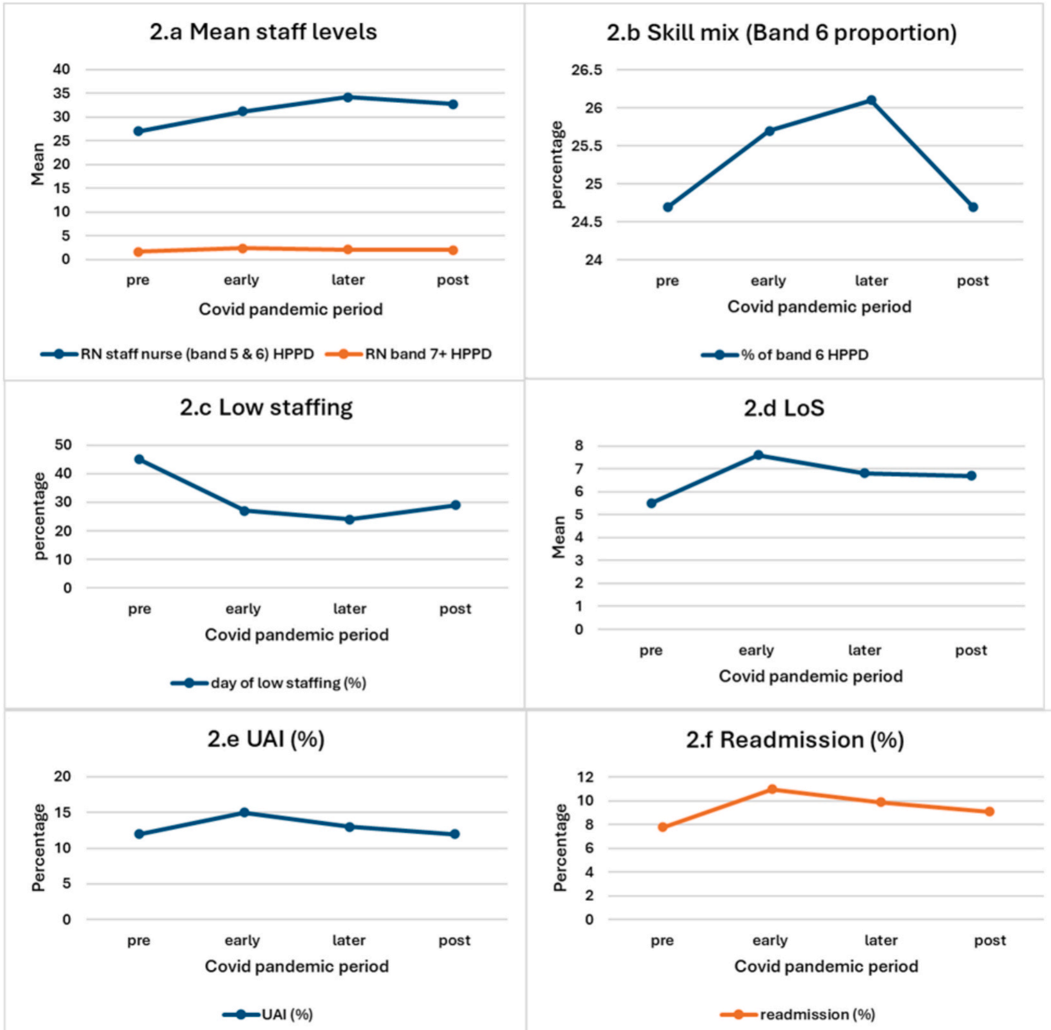

Fig. 2. Change in staffing and staff mix over time (UAI = unit-acquired infections | LoS = length of stay).

Associations between band 7 RN managers and outcomes

Associations between outcomes and hours from band 7 RN managers were mixed. Overall, the presence of low numbers of managers during the stay (as opposed to none) was associated with a 1.3 % reduction in the risk of readmission (AME −0.013, 95 % CI −0.023 – −0.003, p = 0.011). Higher numbers of managers were also associated with reduced risk, although this was not statistically significant, and the effects were smaller. However, the presence of managers was associated with increased length of stay in all periods, although the effect size varied, and not all associations were statistically significant. While there was no overall association between hours from band 7 managers and the risk of unit-acquired infection, in the post-pandemic period, the presence of a low level of managers was associated with increased infection risk, while the presence of higher levels was associated with a significant decrease in risk.

Associations between RN staff nurse skill mix and outcomes

Overall, there were no statistically significant associations between RN staff nurse skill mix and any outcome. However, there were some associations in some periods, with a higher proportion of band 6 staff nurses associated with reduced length of stay in the later pandemic (ratio 0.91, 95 % CI 0.85–0.99, p = 0.019) but an increase in the early pandemic (ratio 1.06, 95 % CI 1.00–1.12, p = 0.038). Although there was no association between increased infections and the proportion of band 6 nurses overall, there was an association between a higher proportion of band 6 staff nurses and increased infections in the late pandemic period and post-pandemic periods (see Table 2).

Association between low staffing and outcomes

Exposure to low staffing, overall, resulted in a higher risk of readmissions and unit-acquired infections, respectively; these associations were not statistically significant (see Supplementary Table 2). In contrast, there was a reduction in length of stay with low staffing (statistically significant).

Discussion

Our study is the first to measure the association between RN staffing configurations and these diverse patient outcomes in the ICU, taking into account periods spanning the COVID-19 pandemic. We found the association to vary depending on the COVID period. Higher RN staffing is consistently associated with reduced readmissions. Prior to the pandemic, higher staffing appeared to be associated with increased length of stay but was associated with reductions later in the pandemic. Associations with hours from RN managers and the proportion of experienced RN staff nurses gave mixed results, with no overall associations with RN staff nurse skill mix. The presence of RN managers was

Table 2
Models for the association of staffing and patient outcomes, including all staffing factors (absolute staffing measure).

	Model (RN Staff nurse HPPD)	UAI			LoS			Readmit		
Time period	*Variable*	*AME*[a]	*95 % CI*	*p-value*	exp (Beta)	*95 % CI*	*p-value*	*AME*[a]	*95 % CI*	*p-value*
All[b]	*RN Staff nurse (SN) HPPD*	−0.005	−0.01, 0.0001	0.057	1.00	0.98, 1.02	>0.9	−0.006	−0.011, −0.001	0.019
	Proportion band 6 SN	0.002	−0.007, 0.01	0.673	0.99	0.96, 1.01	0.3	0.007	−0.001, 0.015	0.096
	RN band 7 + HPPD (ref 0)	—	—		–					
	low (0.1–1.9)	0.009	−0.006, 0.024	0.231	2.22	2.13, 2.31	<0.001	−0.013	−0.023, −0.003	0.011
	medium (2–3.9)	0.001	−0.015, 0.017	0.902	2.00	1.91, 2.09	<0.001	−0.008	−0.021, 0.005	0.205
	high (>=4)	0.007	−0.012, 0.026	0.441	2.07	1.96, 2.19	<0.001	−0.009	−0.025, 0.007	0.265
	AIC / BIC	37317.5 / 37530.2			288764.2 / 288994.6			29029.8/29260.2		
Pre-pandemic	*RN Staff nurse (SN) HPPD*	0.005	−0.012, 0.023	0.534	1.15	1.10, 1.20	<0.001	−0.021	−0.037, −0.006	0.008
	Proportion band 6 SN	0.017	−0.005, 0.040	0.131	0.97	0.92, 1.04	0.4	−0.007	−0.025, 0.011	0.431
	RN band 7 + HPPD (ref 0)	—	—		–					
	low (0.1–1.9)	0.023	−0.004, 0.050	0.091	2.47	2.27, 2.69	<0.001	0.014	−0.011, 0.038	0.274
	medium (2–3.9)	0.006	−0.023, 0.035	0.690	2.02	1.83, 2.22	<0.001	0.014	−0.015, 0.043	0.337
	high (>=4)	0.048	−0.006, 0.101	0.080	2.32	2.03, 2.66	<0.001	0.043	−0.007, 0.092	0.094
	AIC / BIC	9528.9 / 9711.1			75471.0 / 75660.7			7200.6/7360.0		
Early-pandemic	*RN Staff nurse (SN) HPPD*	−0.0096	−0.020, 0.001	0.079	1.02	0.99, 1.05	0.13	−0.011	−0.021, −0.002	0.023
	Proportion band 6 SN	0.011	−0.009, 0.030	0.297	1.06	1.00, 1.12	0.038	−0.004	−0.021, 0.013	0.675
	RN band 7 + HPPD (ref 0)	—	—		–					
	low (0.1–1.9)	−0.021	−0.053, 0.011	0.203	2.73	2.52, 2.95	<0.001	−0.026	−0.048, −0.005	0.016
	medium (2–3.9)	−0.025	−0.060, 0.011	0.175	2.79	2.55, 3.06	<0.001	−0.005	−0.033, 0.022	0.704
	high (>=4)	−0.0002	−0.041, 0.040	0.991	2.81	2.54, 3.12	<0.001	−0.020	−0.051, 0.012	0.227
	AIC / BIC	9953.3 / 10133.2			76203.5 / 76375.9			8301.9/8459.3		
Later-pandemic	*RN Staff nurse (SN) HPPD*	0.0003	−0.013, 0.014	0.962	0.95	0.90, 1.00	0.035	−0.006	−0.017, 0.006	0.361
	Proportion band 6 SN	0.027	0.008, 0.047	0.007	0.91	0.85, 0.99	0.019	0.015	−0.001, 0.032	0.071
	RN band 7 + HPPD (ref 0)	—	—		–					
	low (0.1–1.9)	0.028	−0.002, 0.057	0.067	2.60	2.39, 2.83	<0.001	−0.026	−0.046, −0.005	0.016
	medium (2–3.9)	0.018	−0.015, 0.050	0.281	1.98	1.78, 2.20	<0.001	−0.037	−0.066, −0.007	0.014
	high (>=4)	0.017	−0.021, 0.054	0.376	1.91	1.69, 2.16	<0.001	−0.025	−0.060, 0.010	0.162
	AIC / BIC	9478.9 / 9658.7			73959.5 / 74146.7			7665.6 / 7822.8		
Post-pandemic	*RN Staff nurse (SN) HPPD*	0.013	−0.002, 0.027	0.086	1.06	1.01, 1.12	0.020	−0.005	−0.018, 0.008	0.423
	Proportion band 6 SN	0.034	0.018, 0.051	<0.001	0.97	0.90, 1.05	0.5	−0.007	−0.026, 0.012	0.486
	RN band 7 + HPPD (ref 0)	—	—		–			—	—	
	low (0.1–1.9)	0.039	0.008, 0.070	0.013	2.19	1.99, 2.42	<0.001	0.007	−0.012, 0.027	0.463
	medium (2–3.9)	0.030	−0.004, 0.065	0.087	1.73	1.52, 1.97	<0.001	−0.011	−0.043, 0.022	0.514
	high (>=4)	−0.040	−0.073, 0.007	0.020	1.64	1.41, 1.90	<0.001	−0.003	−0.044, 0.037	0.875
	AIC / BIC	8150.2/ 8311.2			62308.8 / 62469.8			5843.8/5982.9		

All models controlled for admission type, sex, time of day of admission (day or night), month of admission, ICNARC risk score & random effect for ward (unit) | Effect size scaled to SD unit HPPD Hours Per Patient Day | [a]AME Average Marginal Effects | [b] *All* Controlled for year of admission (pandemic period) | Acronyms: RN Registered Nurse; SN Staff Nurse; AIC Akaike Information Criterion.

associated with reduced admissions but increased length of stay. For both these groups, associations varied somewhat across time periods, with both positive and negative associations with length of stay and unit-acquired infections.

The protective effect of RN staff HPPD on readmissions (albeit relatively small) aligns with the evidence from studies across acute hospitals [29,30] but as far as we are aware, this is the first study to demonstrate an association in ICU specifically and across the COVID-19 pandemic. Positive outcomes associated with RN staffing could be due to more RNs allowing for better monitoring, discharge planning, communication and patient education, all of which can reduce the likelihood of readmissions. It is striking that there is also a beneficial association with reduced readmissions associated with hours from RN managers during the pandemic, which is not present at other times. This may reflect a changed role from managerial staff during this period – either delivering more hands-on care in the face of the increased demand for ICU capacity or supporting staff nurses by engaging more in discharge planning.

Findings about the association between managers and length of stay are, on the face of it, perplexing. However, length of stay is an ambiguous quality indicator. While a reduced length of stay may reflect faster recovery and/or absence of avoidable complications, it is also impacted by multiple non-clinical factors, including pressure to discharge to make beds available [31]. Premature ICU discharge is risky, resulting in harm to patients. Decision-making about readiness for discharge is often highly subjective [32] requiring input from the whole team. Nurse managers have more authority in the context of the multi-disciplinary team and a higher level of expertise may mean that their ability to integrate complex information leads to better decision-making [33,34]. Thus, it may be that the presence of managers has a moderating effect on the pressure to discharge, resulting in longer lengths of stay. The association between manager nursing hours and reduced readmissions during the pandemic, when effects on length of stay were greatest, lends some support for this interpretation. These staff are also known to be juggling various roles, diluting the effect of direct care provided. This strengthens the argument for nurses-in-charge to be supernumerary, supported by both theoretical [35] and empirical evidence [36], based on wider impact on work environment. The relationship between positive leadership approaches and improved nurses/patient outcomes has been highlighted in several studies [37,38], and research emphasises the need for them to oversee quality, be visible, approachable and competent [39], highlighting how dedicated time, and not also providing direct care, to be a visible manager on the ICU is crucial for patient safety.

The absence of associations with unit-acquired infections differs from previous studies in ICUs, which reported significant beneficial associations with higher staffing [24,40]. It is unclear why the situation may differ here. On one hand, staffing levels observed in our studies are higher than those typically observed in US studies, where ICU beds are available for a more diverse and lower acuity group of patients. [41] Similarly, staffing levels in a Swiss study were much lower than observed here [24]. Studies also differ in the definition and range of unit-acquired infections, with the ICNARC audit classifying infections from *C. difficile*, MRSA, VRE detected, or antimicrobial treatment initiated after 48 h on the unit. There is scope for ascertainment bias if better staffing leads to more and earlier detection of asymptomatic infection, which may mask associations with quality of infection prevention. While not entirely clear-cut, the fact that there was some tendency from more senior and managerial RNs to be associated with increased infections is consistent with this interpretation.

Implications for workforce planning and future research

This study adds to a body of research demonstrating associations between low nurse staffing and increased patient mortality, including in the ICU [7]. The findings of this study suggest that proper preparation for discharge from the ICU may be an important mechanism through which nurses contribute to positive outcomes for patients. Digital decision-support tools may offer opportunities in future to support with staffing optimisation [42]. However, the significance of increased lengths of stay remains unclear, and further research is needed to understand whether the benefits (in terms of costs and avoided harms) from reduced readmission offset the costs of extended stays.

Strength and limitations

This study has several notable strengths. It was a multicentre study. The longitudinal design and modelling framework allowed for a robust analysis of clustered data, accounting for variability across ICUs. The inclusion of key covariates such as patient acuity and admission type helped control for potential confounders. Despite its strengths, this study has some limitations. Unmeasured confounders such as nurse experience, out-of-hospital care (affecting readmission), and lack of specific risk models for the three outcomes may have influenced the results. For example, patient populations in ICU changed over this time period, with correspondingly different nursing needs, which may not be fully captured by the covariates included. In the length of stay analysis we did not distinguish between deaths and patients discharged alive, although this does give us a measure of resource utilisation. Although the data are longitudinal, the observational design of the study limits the ability to establish causality, and we could not determine the date of events for UAI to ensure staffing exposures preceded the event. We were also unable to determine the deployment of senior RNs in management roles, and so our discussion on how their deployment may have influenced outcomes across the pandemic must be speculative.

Conclusion

This study highlights the critical role of RN staffing in influencing ICU patient outcomes, with higher RN staffing levels linked to lower readmission rates which may be a key mechanism through which RN staffing contributes to overall improved patient outcomes. The complex, context-dependent effects of senior nurses underscore the importance of optimising skill mixes and the deployment of leadership.

Clinical trial registration

Not applicable.

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CRediT authorship contribution statement

Ezekwesiri Nwanosike: Writing – review & editing, Writing – original draft, Visualization, Validation, Methodology, Investigation, Formal analysis, Data curation. **Peter Griffiths:** Writing – review & editing, Visualization, Validation, Supervision, Resources, Project administration, Methodology, Funding acquisition, Formal analysis, Conceptualization. **Chiara Dall'Ora:** Writing – review & editing, Validation, Project administration, Funding acquisition, Conceptualization. **Thomas Monks:** Writing – review & editing, Validation, Funding acquisition, Conceptualization. **Natalie Pattison:** Writing – review & editing, Supervision, Project administration, Funding acquisition, Conceptualization. **Tolusha Dahanayake Yapa:** Writing – review & editing, Validation, Investigation. **Christina Saville:** Writing – review & editing, Validation, Supervision, Project administration, Methodology, Investigation, Funding acquisition, Conceptualization.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: All authors declare funding from National Institute for Health and Care Research (England) (NIHR) as Payment to institution – grant funding to undertake the research. PG, CS and CDO declare funding from NHS England as Payment to institution for undertaking assessments of research relating to safe staffing for national guidance. NP received funding from the RCN foundation and acted as Chair of Trustees and Chair of National Outreach Forum (registered UK charity 1181360): unpaid. If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Data availability

Data-sharing agreements with the organisations that provided data prevent us from sharing data with third parties.

Disclaimer

This paper presents independent research commissioned by the NIHR. The views expressed are those of the author(s) and not necessarily those of the NIHR or the Department of Health and Social Care.

Ethics statement

The research protocol was approved by the Health Research Authority (IRAS 316667 and REC 23/SW/0028), ICNARC Data Access Advisory Group (201401) and the University of Southampton Ethics Committee (ERGO reference: 80440).

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.iccn.2025.104314.

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